Investment Analysis Benefit Guidelines:

Quantifying Benefits from Projected Reductions in National Airspace System Equipment Outages

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1.0 INTRODUCTION

The Investment Analysis and Operations Research Directorate (ASD-400) is responsible for conducting investment analyses and rebaselining major National Airspace System (NAS) acquisition programs. These analyses support the recommendations that are presented to the Joint Resources Council (JRC) for investment decisions.

The objective of this document is to present guidelines for baselining and measuring the Federal Aviation Administration (FAA) benefit and user benefit components due to projected reductions or mitigation in NAS equipment outages. This document establishes a suggested framework by describing steps that analysts working on Investment Analysis Teams (IATs) or on rebaselining programs[1] must undertake when evaluating candidate infrastructure programs that are primarily replacement, service life extension, or technology refresh programs. The steps provide a structured approach so that benefit estimates can be tracked and carried forward in the Acquisition Program Baseline (APB) and/or applied for post-implementation tracking.

A consistent framework is needed so that internal program metrics that are expected to provide benefits can be replicated and consistently applied on a recurring basis. Specifically, this document presents fundamental guidelines with several illustrations of previous IA efforts and provides consistency to the quantification of NAS equipment-related benefits for any specific NAS acquisition that are either candidates for funding or are being funded.

The descriptions that follow support both a JRC 2a and 2b approach leading up to the “official” investment decision.

2.0 SCOPE/DEFINITIONS

The scope of the analysis for each program must be evaluated within the following categories:

- **Operational Domain** - Benefits can be acquired on the ground, terminal airspace, and en route airspace. Delays are typically categorized as departure, arrival, and en route.
- **Benefit Recipients** - Users of the air traffic control (ATC) system, i.e., flying public, scheduled air carriers/commuters, and general aviation.
- **FAA Benefits** - The projected cost savings to the government due to a combination of better equipment reliability, maintainability, and availability that reduces infrastructure and maintenance costs, etc.
- **User benefits** - The projected improvement in flight timesavings, e.g., reduction or mitigation in arrival delays that can be attributed to a new technology, system, service life extension program (SLEP), etc. Savings are provided to the user in terms of direct operating costs: crew, maintenance, fuel and oil, or any combination, and the passenger in terms of saved time. When determining user benefits, the following sub-categories

[1] Typically, rebaselining a program involves re-examining the life cycle cost estimate down to the detailed Work Breakdown Structure (WBS) level. The discussion on FAA benefits is relevant for rebaselining programs.

must be considered: 1) the type of equipment outage – both scheduled and unscheduled outages cause delays, 2) the causes of delay due to an equipment outage – may include weather, NAS equipment, traffic volume and runway congestion.

- **Other Benefits** - Includes the cost of avoided cancellations and diversions in the NAS.

3.0 PLANNING THE ANALYSIS

This document describes a sequence of seven steps that should be applied to measure the impact or contribution of the acquisition or non-material solution. Discussion for each step with illustrations from the Power Systems IA and the ongoing Airport Surveillance Radar-9 (ASR-9)/Mode-Select (Mode-S) IA are presented. Note: Subsequent steps (Review and Coordination and Completion of the Final Report) annotated in the Standard Benefit Analysis Methodology [19] are not addressed in this document. Figure 1 presents the steps in conducting a benefits analysis; descriptions of each step follow.

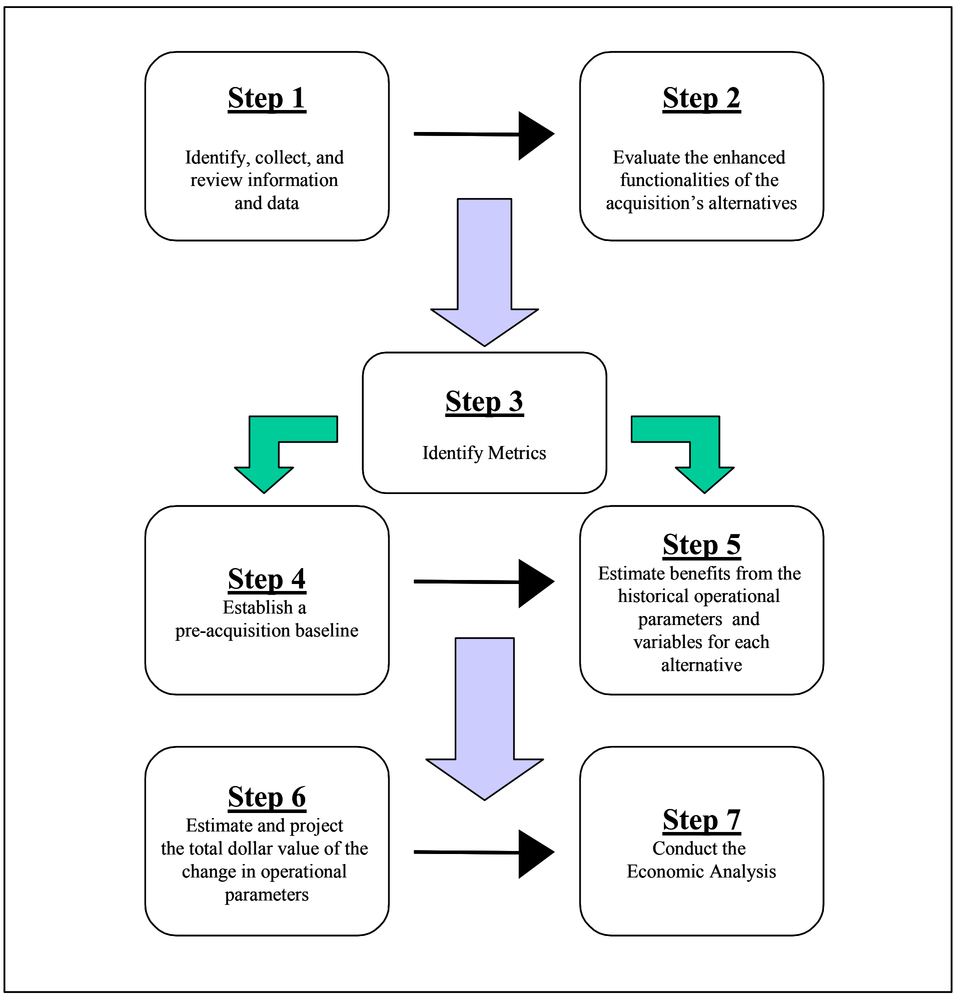

Figure 1. Steps in Conducting a Benefits Analysis

3.1 Identify, Collect, and Review Information and Data Needed for the Analysis - Step 1

Step 1 identifies and assesses the enhanced capabilities that the acquisition will provide. It also includes completing a preliminary analysis to better understand the program by evaluating and cross-walking documents such as the Mission Need Statement (MNS), the initial Requirement Document (iRD), the Concept of Operations, and the NAS Architecture documents either before or after the IA kick-off.[2] In addition, through the Investment Analysis Plan (IAP) the Integrated Product Team (IPT), the sponsor, and ASD-400 may need to coordinate and develop formal mechanisms, i.e., a Memorandum of Understanding (MOU) or Memorandum of Agreement (MOA), on the data requirements (as best as can be expected) before the IA officially begins. Furthermore, pertinent trade studies, including benchmarking studies and any evaluations that have been completed in the recent years need to be evaluated. To ensure this part of the work does not become redundant and superfluous, it is important to examine ongoing efforts to assess the capabilities of the acquisition.

It is critical that the team identify the resources, including data sources, tools, (see http://www.faa.gov/asd/ia-or/pdf/Conducting_a_Benefit_Analysis-7a-The_Art.pdf, Appendix E) and reference documents for both developing a performance baseline of the "reference case" and forming a basis for projecting the future benefits. The following is a representative set of assumptions and data needs that should be identified. The italicized text emphasizes key elements of the assumptions that must be performed for each analysis.

Infrastructure Program Assumptions:

- *Existing infrastructure functionality* will be maintained throughout the analysis period.
- Data on *historical failure rates and maintenance costs* for individual equipment systems/sites may not be available to the team.
- The *duration of the life cycle* will vary for each program.
- The *preventive and corrective maintenance philosophy* will either remain the same or change with the alternative acquisition.
- The improvement in the reliability, maintainability and availability may occur from the replacement technology.

Infrastructure Program Data Needs:

- Facility performance trends: operational availability, inherent availability, reliability, maintainability, mean time to restore (MTTR),[3] mean time between outage (MTBO), and scheduled and unscheduled outages - Source: National Airspace System Performance Analysis System (NASPAS)
- Sparing: inventory by line replaceable unit (LRU) and national stock number (NSN), historical expenditures, and logistical support - Source: Program Office, Logistics Center

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[2] As of mid-2003 Investment Analysis Readiness Reviews (IARRs) are required before an Investment Analysis can originate. A quantification of the claimed shortfall is necessary during this phase.

[3] MTTR will be referred to as mean time to restore throughout the report.

- Maintenance workload (preventive and corrective) - Source: Airway Facility Staffing Standards (SSAS)
- Infrastructure requirements for replacement NAS systems - Source: iRD
- Standards of tolerance, applicable standards, laws, codes, and regulations
- Total inventory, sites, age of facilities, and commissioning dates - Source: Facility Service Equipment Profile (FSEP)
- Requirements (key system requirements, program requirements) - Source: MNS and iRD
- Other data that supports the inputs for the application of the System Outage Disruption Model (SODM) - see Table 8

3.2 Evaluate the Enhanced Functionalities of the Acquisition's Alternative(s) - Step 2

Step 2 involves implementing a structured evaluation approach to assess the claimed improvements of the alternatives when compared to the reference case. There are several issues, most of which are addressed in the MNS, that need to be evaluated, i.e., understanding how the shortfall can be addressed that include:

- What user inefficiencies will this acquisition address?
- What will the acquisition physically or operationally do?
- What parts of the FAA and aviation community will it affect?
- How many sites are involved? Where are the sites? What proportion of the aviation community will benefit from the acquisition?
- What other programs need the capability to enhance their benefits, i.e., is this an enabling technology for other current programs or planned initiatives?
- How will the acquisition impact both the users and providers?
- Does the data provide a further breakdown by type of delay during an outage, e.g., equipment delays, weather delays, volume delays, runway delays, etc?

The analyst(s) needs to do as complete of an internal assessment as possible to give this step clear direction. Candidate decision processes that impact the performance objective need to be assessed and documented in detail in the Investment Analysis Report (IAR).

3.3 Identify the Relevant Metrics - Step 3

The analyst(s), working with the sponsor and the IPT, identifies and selects the metrics that are quantifiable, measurable, and expected to show an improvement based on anticipated performance from the investment. The following representative metrics have been identified as part of the Air Traffic Organization (ATO) performance indicators: 1) system availability, 2) delays due to outages, and 3) number of service actions (this can be considered the number of maintenance actions which correlates to Table 3).

The IPT should determine what metrics can be supported over time (with sufficient data) and should be accountable via the APB for improved performance including cost savings to the FAA and/or the user.

3.4 Establish a Pre-Acquisition Baseline - Step 4

Step 4 establishes a pre-acquisition baseline derived from historical data to support the metric(s) identified as traceable and that are expected to provide a benefit once the acquisition is deployed. It is important that this baseline be established using the relevant data before other scenarios or alternatives of the life cycle are estimated, and that the ground rules and assumptions are identified. The pre-acquisition baseline, which can be viewed as the situation that has existed over time with the legacy system, must evaluate the various historical performance measures, i.e., availability, maintainability, maintenance workload, reliability, delay impact from an outage, etc. Performance data illustrations for Power Systems and ASR-9/Mode-S presented in this section include:

- Annual delays and delay event summaries by facility and service area
- Availability and reliability
- Unscheduled outages (time, events, cause codes)
- NAS equipment delays by facility
- NAS equipment logs

It is also important that the caveats and limitations that help characterize the integrity and accuracy of the benefit estimation are annotated. Misinterpretations in the collected data will unquestionably occur; however, in the aggregate, the averages with large sets of data points will be meaningful for the purposes of establishing a baseline. Several of the Airway Facilities (AAF) performance parameters can be garnered from the 6040 NASPAS and System Consolidated Outages for Operations (SCOOP) reports. There are several NAS performance reports available (via special request) through NAS Quality Assurance Division (AOP-200). Many of the tables and graphs that follow are based on the information of commonly tracked performance measures from these NASPAS reports. The following examples were applied to the Power Systems IA and the upcoming ASR-9/Mode-S SLEP IA.

3.4.1 ASR-9/MODE-S Performance Attribute Illustrations

Table 1 shows the *annual Operational Performance System NETwork (OPSNET) reported delays* attributed to an ASR-9/Mode-S outage, and Table 2 illustrates a high-level historical performance summary of key performance measures. Over a five-year period, there were 100 reported ASR-9 delay events causing 1,779 delays, and 30 Mode-S delay events causing 761 delays.[4]

[4] All OPSNET reported delays are 15 minutes or greater.

Table 1. Historical ASR-9 and Mode-S Annual Delays

Facility	1998 Events	1998 Delays	1999 Events	1999 Delays	2000 Events	2000 Delays	2001 Events	2001 Delays	2002 Events	2002 Delays
ASR-9	11	280	26	414	23	622	19	196	21	267
Mode-S	6	155	9	279	8	293	1	21	6	13

(Source: OPSNET)

Table 2. Key Historical Performance Parameters for ASR-9 and Mode-S

Facility	# of Outage Events Causing Delays (98-present)	# of Delays (97-present)	Operational Availability- A_o (97 present)	Inherent Availability A_i (97-present)	Reliability	MTBO (years/hours)
ASR-9	100	1779	.995	.9995	.997	.601/5261
Mode-S	30	761	.997	.9996	.999	.772/6762

(Source: OPSNET and NAPRS)

Figure 2 illustrates the behavior of the *operational availability*, often referred to as A_o, of the ASR-9/Mode-S and for a three and one-half year period from October 1999 through March 2003. A_o (which is defined as the maximum operational time, minus the total outage time, divided by the maximum operational time) is a very useful measure for identifying the downtime for a given facility. For example, 99.5 percent availability for ASR-9 indicates that on average a facility was down 44 hours per year. A_o is different from A_i in that it does not consider operational influences such as unavailable maintenance policies and spare parts. A_i is defined as [1-MTTR/(MTBO+MTTR)]. MTBO is another very useful measure to track outages. The 5,261 hours in the right most column indicates that every 5,261 hours, there is an outage among the ASR-9s in the NAS. MTBO is defined as the maximum available hours, minus the total outage time, divided by the total number of outages.

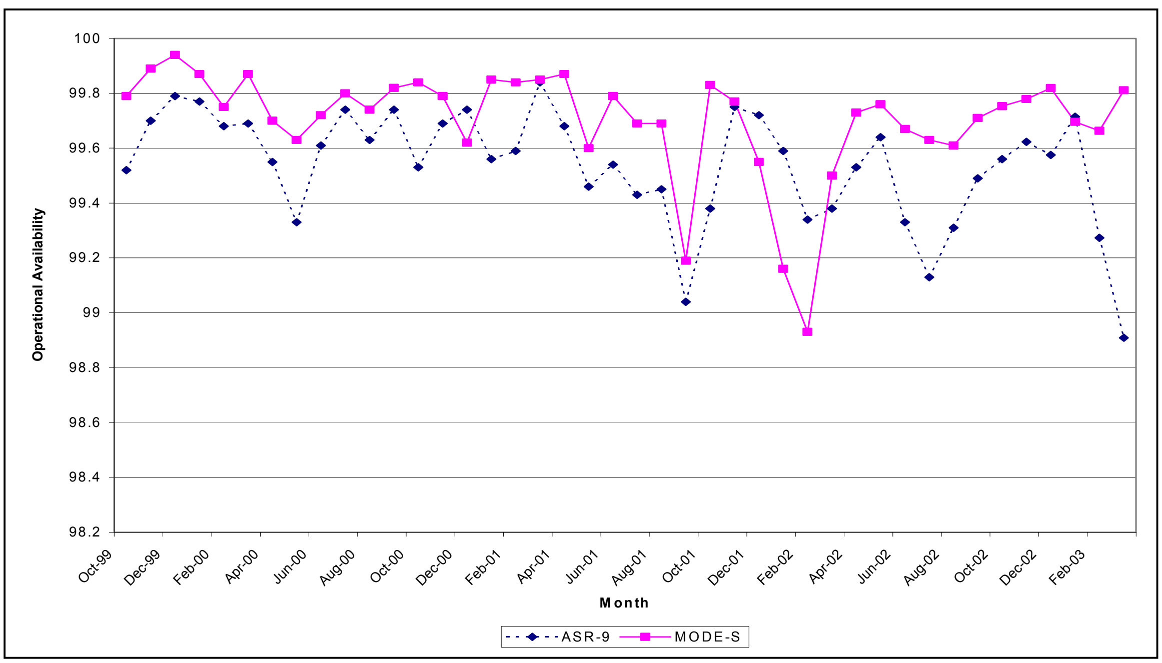

Figure 2. Operational Availability Trend (10/1999-3/2003)

Table 3 and Figure 3 show the number of historical events associated with each unscheduled outage cause code for the ASR-9. Furthermore, scheduled outages by cause codes can be evaluated in a similar fashion. Combining Tables 2 and 3 and the scheduled outage causes can assist the analyst in determining the *probability of an outage given a reported air traffic delay*.[5]

Table 3. Unscheduled ASR-9 Outages by Cause Code (1997-2002)

Unscheduled Causes	1997	1998	1999	2000	2001	2002	Total (97-02)	Percent of Total
80 Equipment	92	115	93	81	97	102	580	48%
81 Commercial Use	2	4	1	0	1	4	12	1%
82 Prime Power	68	47	18	18	16	14	181	15%
83 Standby Power	23	17	12	12	7	12	83	7%
84 Interference Cond.	0	1	1	0	0	2	4	1%
85 Weather Effects	11	7	7	7	10	47	89	7%
86 Software	0	0	0	0	0	0	0	
87 Unknown	23	14	5	4	6	69	121	10%
88 Related	7	0	2	1	1	14	25	2%
89 Other	14	9	9	10	4	61	107	9%
Total	240	214	148	133	142	325	1202	100%

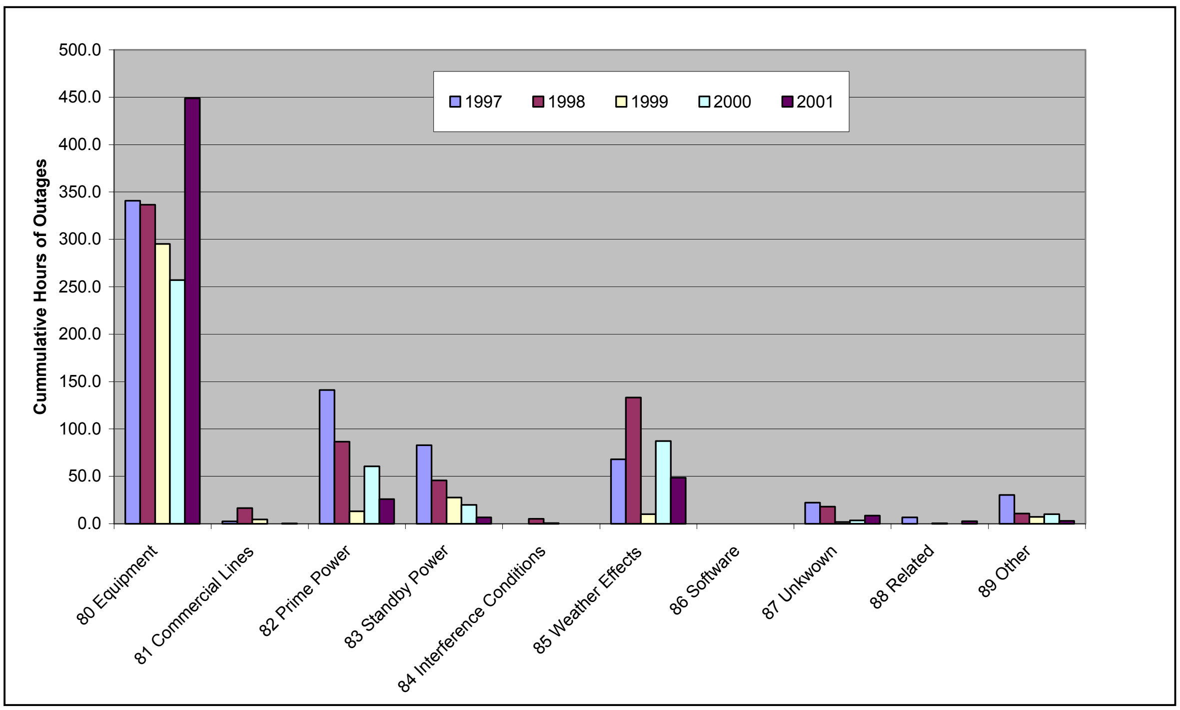

Figure 3. Illustration of ASR-9 Unscheduled Outages by Cause Code

[5] It is recommended that code 65s scheduled corrective maintenance also be evaluated since several reported delay events have cause code 65 associated with them.

3.4.2 Power System Performance Attribute Illustrations

Similar to examining the historical performance attributes of the ASR-9/Mode-S, the historical performance trends of the FAA's facilities that incur power outages are shown in Figures 4, 5, and 6 using National Airspace Performance Reporting System (NAPRS) data for the 11-year period (FY88-FY98). Three measures: *annual outage occurrences, annual duration,* and *hours per outage duration* imply a larger maintenance workload for both the primary power and standby power outages.

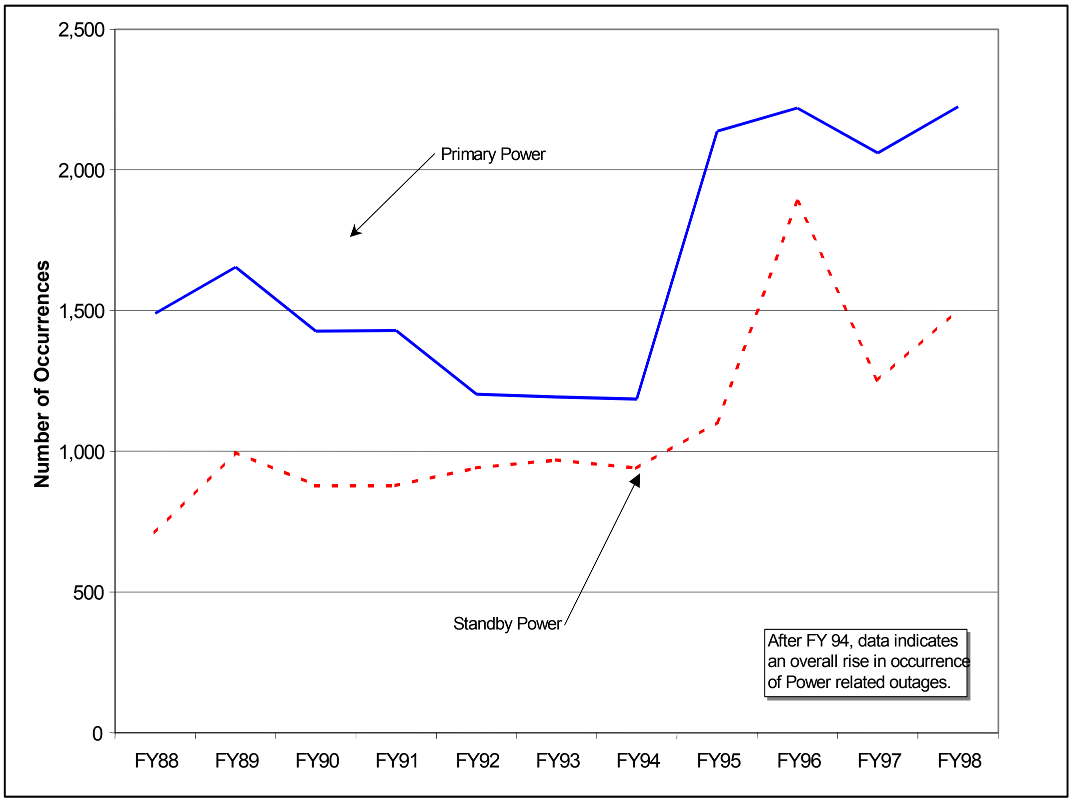

Figure 4. Annual Outage Occurrences for Primary and Standby Power *(Source: NAPRS)*

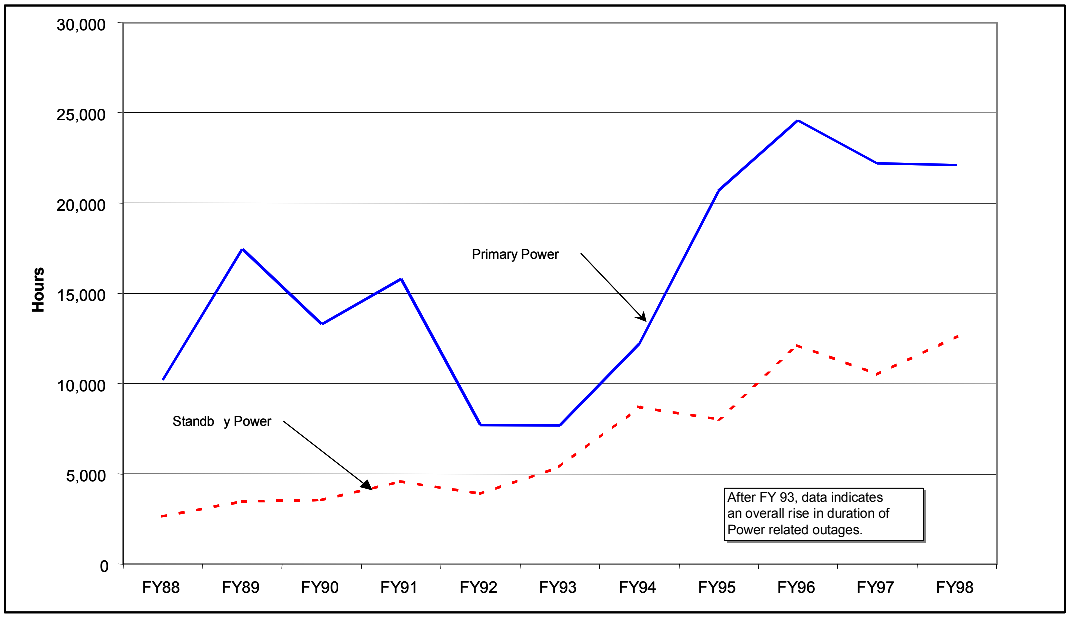

Figure 5. Total Annual Duration of Primary and Standby Power Outages *(Source: NAPRS)*

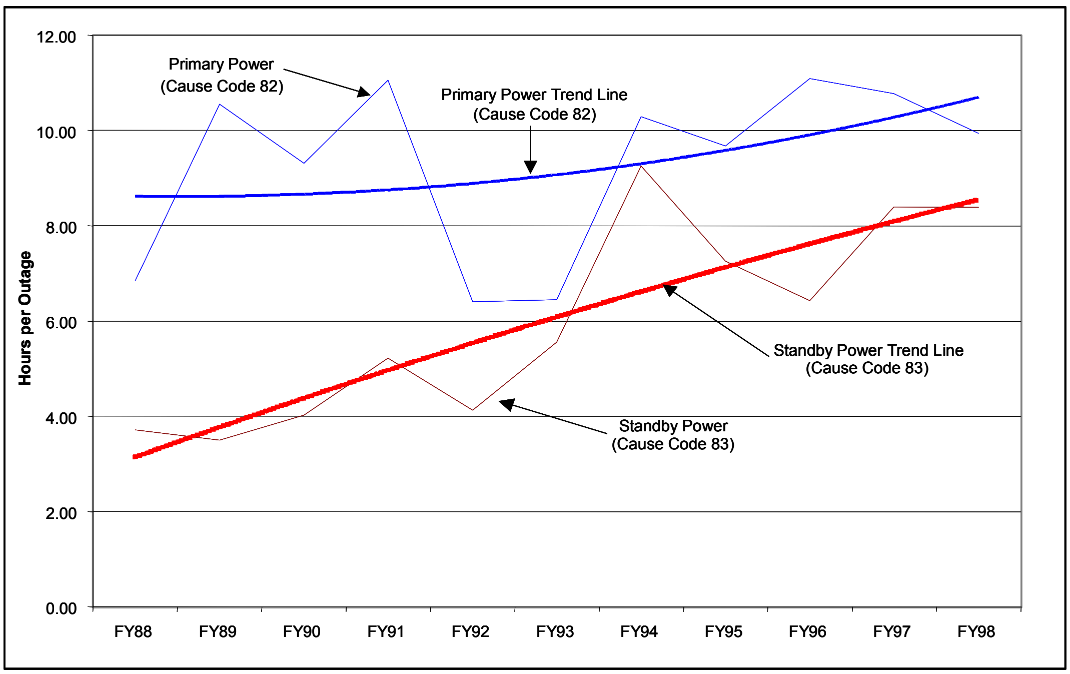

Figure 6. Hours per Outage for Primary and Standby Power

3.4.3 Power Related Delays

The AFTECHNET web site (http://aftechnet.faa.gov) identifies outages that incurred delays; the delays are collected and tracked through OPSNET. The historical delay profile of a facility or service *causing a power outage* over the past three years since 2000 is presented in Table 4. Generally speaking, because of the redundancy in the NAS, there is a very small likelihood (approximately 1-2 percent), regardless of whether it is a scheduled or unscheduled outage, that a reported outage will cause a an OPSNET reported delay. Despite a history of several unscheduled outage hours attributed to an unscheduled *primary power event* (code 82), the data clearly shows that since 2000, there have been only four *unscheduled primary power events* that causing 33 reported delays to the NAS; whereas there were 22 *unscheduled standby power events* (code 83) that caused 1,319 delays in the NAS.

Table 4. Facility/Equipment Delays Caused by Power Outages (2000-present)

Loc	Type	Region	Date	Accepted Delays	Validated Delays	Type of Delay	Cause	Service Area	Cause Code
INB	LOC	AWP	9/3/03	8	8	Arr, Dep	Power	Nav	82
QHM	PCS	AEA	8/17/03	157	157	Arr, Dep, Enroute	Power	Power	83
CLT	ARTS	ASO	8/12/03	7	7	Departure	Power	Auto	83
PBI	RTR	ASO	8/10/03	2	2	Departure	Power	Comm	83
MDW	TOWB	AGL	7/12/03	1	1	Departure	Power	Other	NR
SJW	LOC	ACE	4/7/03	4	4	Departure	Power	Nav	83
PBI	TCOM	ASO	4/2/03	17	17	Departure	Power	Comm	83
SDF	ARTS	ASO	3/27/03	1	1	Departure	Power	Power	82
CVG	ASR	ASO	2/16/03	12	12	Departure	Power	Power	83
CVG	ASR	ASO	2/15/03	3	3	Departure	Power	Surv	83
EWR	GS	AEA	12/11/02	21	21	Arrival	Power	Nav	NR
SPS	ECOM	ASW	8/26/02	4	4	Departure	Power	Comm	83
ELP	SX	ASW	8/2/02	19	19	Departure	Power	Power	83
MCC	PCS	AWP	7/10/02	13	13	Arr, Dep	Power	Power	83
CLT	PCS	ASO	7/2/02	23	23	Arr, Dep	Power	Power	82
QXQ	ECOM	ANM	6/9/02	2	2	Arr, Dep	Power	Comm	83
MSY	PCS	ASW	6/4/02	12	12	Arr, Dep	Power	Power	NR
RSG	ECOM	ASW	3/12/02	29	29	Departure	Power	Comm	83
ZMP	PCS	AGL	8/24/01	1	1	Departure	Power	Power	87
ZMP	PCS	AGL	8/23/01	6	6	Enroute	Power	Power	87
SBA	LOC	AWP	8/8/01	1	1	Arrival	Power	Nav	82
GPT	RTR	ASO	7/29/01	12	12	Departure	Power	Surv	80
ENA	ARSR	AAL	7/28/01	1	1	Departure	Power	Comm	83
STLK	SX	ACE	7/6/01	15	15	Departure	Power	Power	83
STLK	SX	ACE	7/5/01	4	4	Departure	Power	Power	83
RDU	TCOM	ASO	6/17/01	2	2	Departure	Power	Power	83

Table 4. Facility/Equipment Delays Caused by Power Outages (2000-present) Cont'd

Loc	Type	Region	Date	Accepted Delays	Validated Delays	Type of Delay	Cause	Service Area	Cause Code
IAHA	PCS	ASW	6/7/01	125	125	Departure	Power	Power	NR
TUL	PCS	ASW	4/26/01	6	6	Departure	Power	Power	83
TWI	ALS	ACE	4/4/01	1	1	Arrival	Power	Power	83
ZSU	PCS	ASO	2/21/01	65	65	Departure	Power	Power	83
ZID	CRAD	AGL	11/1/00	6	6	Departure	Power	Power	83
ZID	CRAD	AGL	10/31/00	945	945	Departure Enroute	Power	Power	83
ZID	CRAD	AGL	10/30/00	5	5	Departure, Enroute	Power	Power	83

Code 80 = Unscheduled Equipment Power Outage
Code 82 = Unscheduled Primary Power Outage
Code 83 = Unscheduled Standby Power Outage
Code 87 = Unscheduled Weather Power Outage

Table 5 shows a sample "NAS Equipment and Related Delays - Event Details Page" of an outage that occurred on October 31, 2000, at Indianapolis Airport (ZID) that caused 945 delays.

Table 5. NAS Equipment and Related Delays: Event Details Page

Facility ID:	ZID	**Facility Type:**	CRAD
City:	INDIANAPOLIS	**State:**	IN
SMO:	GL3	**Region:**	AGL
Cost Center Code:	083AJ	**OPI:**	AGL

Delay Date:	10/31/2000	**Event Date:**	10/31/2000
Arrival Equip Rep.:	0	**Arrival Other Rep.:**	0
Departure Equip Rep.:	943	**Departure Other Rep.:**	0
Enroute Equip Rep.:	2	**Enroute Other Rep.:**	0
Equip. Delays Reported:	945	**Other Delays Reported:**	0
Equip. Delays Accepted:	945	**Other Delays Accepted:**	0
Reconciled Delays:	945	**Reconciliation Date:**	11/1/2000
Day of Week:	Tuesday	**Quarter Day (Local):**	16:00-17:00
Start Date:	10/31/2000	**End Date:**	11/1/2000
Start Time (z):	2105	**End Time (z):**	0407
Duration:	0 day(s) 7 hour(s) 2 minute(s)		

Reconciliation Remarks:	None

NAS Area:	En Route	**Svc. Area:**	Power
General & Sub Cause:	Pwr-Stby-UPS/PCS		
NAPRS Code:	83-Standby Power		
Delay Type:	NAS Equipment	**Tech_On_Duty:**	On Duty
Service Delivery Point:	ZID	**MMS ID:**	ZID-00-135301

Remarks:	At 4:05 PM EST, the Indianapolis, IN (ZID) Air Route Traffic Control Center (ARTCC) experienced an internal critical power problem that interrupted all air/ground communications, radar displays, and automation systems. The four (4) Engine Generators were manually adjusted and stabilized prior to placing them on line to restore power to the critical bus at 4:07 PM.

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3.4.4 Delays by Service Area

Finally, a summarization of *OPSNET reported delays by NAS service area* is presented in Table 6. This table identifies all facilities and equipment types that have experienced delays 15 minutes or more from outages over the past six years. The table also portrays a broad perspective of the historical delays from outages for the particular equipment impacted by the acquisition being evaluated. The service areas are automation, communication, navigation and landing, surveillance, power, and other. The automation service area experiences the most delay. It incurs about 30 percent of the reported delay events, while incurring about 60 percent of the delay time among the service areas. The equipment types that have the *most reported outages causing delays* in this timeframe are the ASRs, Automatic Radar Terminal System (ARTS), En Route Communications (ECOM), Terminal Automated Radar Service (TARS), ILS Localizer (LOC), and Terminal Communications Service (TCOM). Note: All equipment types in the "Type of Equipment" column are identified in Order 6040.15, NAPRS and the Facility Service Equipment Profile (FSEP) that is available through the AFTECHNET web site. An updated version is maintained in the ORLAB.

Table 6. Equipment with Reported Delays by Service Area (October 1997- September 15, 2003)

Service Area	# of Delay Events	# of Reported Delays	Type of Equipment Delays Attributed To
Automation	426	15,967	STARS, ARTS, TARS, CCCH, CDC, CFAD, NADIN, IDAT, RTADS, DSR, MICROEARTS, FDIOC, FDIOR, DCCR
Communication	233	3,245	ECOM, TVS, TCOM, IDAT, ICSS, TRACON, VSCS, VSCSS, RVDS, RMLT, RDVS, RCAG, SACOM, ATCT, RTR, FOTS
Navigation and Landing	182	2,393	RVR, GS, LOC, PRM, PAPI, TALR, ILS, VOR, ALS, VASI, LLWAS, DME, MALSR, NDB
Surveillance	252	4,344	ASR, Mode-S, ATCBI, BDAT, TRAD, ATCRB, TARS, ARSR, ASDE, CD
Power	20	1,799	ARTS, SX, PCS, TCOM, ALS, CRAD
Other	187	629	Most are not identified. Other categories include ATCT, TOW, ARTCC and ASOS

3.5 Estimate Benefits from the Historical Operational Parameters and Variables for Each Alternative - Step 5

This step describes how to develop user benefits and FAA benefits (avoided costs) for NAS infrastructure programs that will be instrumental in mitigating or reducing outages. The following programs appear to have strong justification to claim both types of benefits:

- Alaskan National Airspace System Interfacility Communication System (ANICS) - CIP #4C10
- ASR-9/Mode-S Sustainment program - CIP #2A01G
- Electrical Power Systems (Power Systems Sustained Support) - CIP #4C11
- En route Communication Gateway (ECG) - CIP #4B01
- En route Automation Modernization (ERAM) - CIP #2B02
- Flight Service Station Modernization (includes power conditioning system upgrade) - CIP #4C06
- Instrument Landing System Establishment/Upgrade - CIP #3A01D

- NAS Infrastructure Management System (NIMS) - CIP #4C05
- Standard Terminal Automation Replacement System (STARS) - CIP #2A01
- Terminal Voice Switch Replacement/Enhancement - CIP #4A02
- Test Equipment Modernization/Replacement - CIP #5A15
- Voice Switching and Control System (VSCS) - CIP #3A03

Additionally, this step captures the differences between the baseline case (reference case) and the different acquisition alternatives, if applicable. In some cases, the various alternatives will give different levels of capabilities and improvements. Typically, infrastructure programs are dominated by FAA benefits (avoided costs). However, if the IAT feels that user benefits can be realized, e.g., STARS will have fewer outages causing delays than its replacement system ARTS IIIa, and then they should be quantified. Therefore, it is important to address the impact to the user of the expected reduction in outages that causes disruptions.

3.5.1 User Benefit Impact

This part of the benefits analysis measures the added value from an expected reduction in outages that causes disruptions of the different acquisition alternatives to the user, i.e., air carriers, commuters, general aviation operators, etc.

3.5.1.1 User Benefit Checklist

Table 7 provides a checklist that can be applied when scoping the user benefits.

Table 7. Checklist of User Delay Benefits

Monetized Metric	User Delay Benefits Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
* Value of passenger time saved * Value of aircraft operating cost saved	* Number of flights with reduced delays * Number of flights with reduced airborne times, ground times, etc. * Number of reduced cancellations * Number of reduced diversions * Total aircraft operating time/cost saved from reduced delays * Assess delay reductions for: – Flights * En route * Ground * Terminal * Assess disruption reductions for: – Canceled flights – Diverted flights * Assess other impacts for: – Air carrier – Commuters and air taxi – General aviation – Military * Number of passengers with reduced delays * Total passenger time saved with reduced delays	* Change in weather caused delays: – Take-off delays due to poor visibility, snow, convective weather, etc. – Weather diversions * Change in separations due to wake vortex mitigation, i.e., less MIT restrictions * Change in controller workload induced delays * Reduction in airspace capacity which increases delays during heavy traffic * Reduction in airport acceptance rates (e.g., Center Radar Approach Control (CENRAP), Direct Access Radar Channel (DARC) due to equipment outages * Number of outages that incurred a reported OPSNET delay

3.5.1.2 SODM - Overview

The SODM was developed to assist analysts with estimating the magnitude of potential NAS arrival delays resulting from air traffic system outages. The model generates a probability distribution of the amount of delay caused by system component outages relative to the baseline year, and is used to estimate the impact of alternative NAS system designs and implementation schedules. Departure delays, cancellations, and diversions are extrapolated from the modeled results and are described in Appendix A of this report.

In particular, the SODM can be used to estimate the reduction in delays from the future years that are assumed to have improved availability and/or restoral rates of a new or improved Air Route Traffic Control Center (ARTCC) or terminal component. The SODM is a useful tool for measuring both projected user benefits between alternatives or scenarios within alternatives. It projects the future NAS delay of the respective facility (airport or ARTCC) based on varying inputs such as mean time between failure (MTBF), MTTR, probability of delay, and reduced airport capacity.

In the model, NAS delay accumulates when demand exceeds the airport capacity during each outage and the total excess demand (flights) during a randomly generated outage. The frequency of occurrences for outages is based on the MTBO between the respective facilities. Aircraft unable to land within their scheduled arrival time "spill" into the next bin causing a delay. The delay time illustrated in Figure 7 (generated by SODM) is attributable to the differences in the projected changes in the parameters from the three cases. Future delay increases are related to the rate of increase of operations identified in the Terminal Area Forecast (TAF) relative to the growth in the airport capacity.

3.5.1.3 SODM - Data Sources

Table 8 provides data sources that are necessary for both the inputs to SODM and the post-processing of the simulated results.

Table 8. Data Sources

Data Source	Capability	Application in the Analysis	Source
NAPRS	Primary data source available through NASPAS– reports key reliability, maintainability, and availability parameters, which include outage hours, outage events, availability, MTTR and MTBO by facility. The details are described in Order 6040.15D.	SODM inputs	AOP-200
Airline Service Quality Performance (ASQP)	Captures "on-time" reporting performance for 10-12 major carriers. Information provided includes delays, flight times, cancellations, and diversions.	Calibration, extrapolation to account for cancellations and diversions	DOT
Operations Network (OPSNET)	Official FAA delay reporting system through Order 7210.55B. Captures all reported delays>= 15 minutes by cause (including equipment related delays).	Basis for validating the probability of an outage causing a delay given a reported delay	ATT-200
Maintenance Management System (MMS)	Provides all logged maintenance actions for a given system, reports failures/outages by cause code with comments.	Complements NASPAS analysis with supporting details	AOP-200
TAF	Contains current and projected operations and enplanements for the majority of the NAS airports.	Projects additional traffic demand and used for extrapolation to additional to airports	APO-130
Official Airline Guide (OAG)	Contains all scheduled flights.	The hourly scheduled arrival demand from each airport	APO-130
Enhanced Traffic Management System (ETMS)	Contains all "as flown" and "filed" flight plans for all aircraft.	Provides hourly non-scheduled arrival demand (typically general aviation and air taxi)	ATA-200

3.5.1.4 SODM Input Parameters - ASR-9 and Mode-S

Table 9 illustrates how SODM is being applied in the ongoing ASR-9/Mode-S IA that will support an early-2004 JRC 2a investment decision. It annotates the key preliminary assumptions to SODM's key operational input parameters that were made for the different investment alternatives[6] at the onset of the ASR-9/Mode-S SLEP IA.

[6] Quantifying each alternative is required for a JRC 2a investment decision when multiple alternatives are being evaluated for cost, benefits, schedule, and risk.

Table 9. ASR-9/Mode-S Parameters

Parameters	Alt. 0: Reference Case (LRU by LRU Sustainment)	Alt. 1: ASR-9/Mode-S Site Approach	Alt. 2: ASR-9 SLEP/ ATCBI-6	Alt. 3: Acquire Replacement Radar (Integrated Primary/Secondary)
Airport Capacity	Max arrival capacity with allowances for new and expanded runways, procedures, etc. Adjustments made through 2020, straight-lined through 2027.	Same as Reference Case	Same as Reference Case	Same as Reference Case
Airport Capacity Reduction Factor	20% adjustment based on combination of primary and secondary radars or both are down. No assumption for loss of CENRAP that puts terminal or TRACON in a non-radar environment.	Same as Reference Case	Same as Reference Case	Same as Reference Case
Mean Time to Restore (MTTR)[7]	Current average restoral times are 3.2 hours for ASR-9; 7.2 hours for MODE-S. Restoral times increase slightly; 2008-2012 increase 1%; 2013-2016 increase 2%, beyond 2016 increase 3%.	2.25 hours for both systems based on four annual preventive or corrective maintenance actions per site to achieve, .999 A_o i.e., 8.76 hours annual downtime hours per site. This occurs 6 months after planned implementation.	Same as Alternative 1	Same as Alternative 1
Mean Time Between Outage (MTBO) *See Section 5.0*	Current A_o for ASR-9 is .995; Mode-S is .997. Three adjusted availability levels to .98, .95 and .90. by 2027.	Every 2190 hours; [(8760-8.76)/4]. To maintain an A_o of .999.	Same as Alternative 1	Same as Alternative 1

[7] Mean Time to Restore is different from Mean Time to Repair, which is also frequently designated as MTTR. Mean Time to Repair, which typically is annotated with a requirement of 30 minutes in the iRD and Final Requirements Document (fRD), is one of the components of Mean Team to Restore. Other variables that impact the Mean Time to Restore include testing and certification, travel and time spent waiting for parts. It can be thought of as the time it takes to restore a system from a failed state to an operable state.

Table 9. ASR-9/Mode-S Parameters, Cont'd

Parameters	Alt. 0: Reference Case (LRU by LRU Sustainment)	Alt. 1: ASR-9/Mode-S Site Approach	Alt. 2: ASR-9 SLEP/ ATCBI-6	Alt. 3: Acquire Replacement Radar (Integrated Primary/Secondary)
Airport Demand	Using ATADs as base, hourly demand adjusted each year from ETMS and/or OAG to account for the growth in the terminal traffic forecasts.	Same as Reference Case	Same as Reference Case	Same as Reference Case
Implementation schedule (first unit to last unit, two per month)	2005-2027 re-designing several sub-assemblys each year	2011-2016 (New architecture)	2011-2016 (New architecture)	2012-2017 – 1 year slip from SLEP alternatives

Equipment outages may result at the airport or ARTCC. Frequently, the airport capacity is reduced to a lower acceptance rate during the outage event. The reduction is dependent on judgment of the air traffic of how best to maintain NAS operations without compromising safety, given the loss in capability, i.e., loss of a primary channel. This model directly estimates the effects of equipment outages on NAS flight arrival delays. It does NOT directly estimate "downstream" disruption, such as delays in a region served by a second ARTCC that is caused by an outage at a first ARTCC. This model also does not directly estimate departure delays.

SODM simulates delays for any airport as long as the appropriate information is available, i.e., hourly demand, maximum arrival capacity, MTTR, MTBO, and the implementation schedule. Using the demand during system outages, SODM generates median annual delay in minutes from 1,000 iterations using terminal hourly demand with the growth rates applied consistent with the FAA's TAF projections.

3.5.1.5 Projecting Future Trends of Parameters

It may not be obvious how to project the parameters in Table 9 that impact the future outage trends that cause delays. In addition, reduced restoral times and less frequent outages should be reflected in some of the Work Breakdown Structure (WBS) cost elements that are dependent on these parameters. Once the analyst establishes a solid foundation for establishing the baseline parameters (as part of the pre-acquisition baseline through the combination of the data sources such as the NASPAS and the OPSNET), then different techniques can be applied to develop the assumptions. These techniques for developing multi-year trends include gathering expert opinion from members of the Investment Analysis Team (IAT) and performing statistical analyses using the historical data. Polynomial, exponential, logarithmic, power, and linear regression techniques can be applied to the data sets. A comprehensive set of candidate statistical tests are described in *The Art of Benefits Prediction and the Statistical Science of Post-Implementation Assessment in Aviation Investment Analysis [17].*

3.5.1.6 SODM Application - Power Systems

Input system performance parameters for four scenarios were developed during the Power Systems IA (similar to how SODM was applied for the ASR-9/Mode-S IA, see Table 9). These scenarios were developed through consultation with subject matter experts (SMEs) who based their advice on industry data and the "Health of ACEPS Study" (see bibliography). For example, the Power Systems IA Benefits Team used system performance parameters for four scenarios that it evaluated for each of the six investment alternatives. An example of the *preferred alternative* with the four scenarios is presented below:

- **Scenario 1:** Current reference case. The system availability sustained (no future degradation).
- **Scenario 2:** <u>2% annual degradation</u> in availability. The MTBF and MTTR degrade by 2% per year over the life cycle
- **Scenario 3:** <u>3% annual degradation</u> in availability. The MTBF and MTTR degrade by 3% per year over the life cycle.
- **Scenario 4:** <u>20% improvement</u> in availability. (Based on new power equipment, the MTBF and MTTR will improve 20% over current levels. This improvement takes effect in 2005 and remains constant through duration of the life cycle.)

Table 10 illustrates these performance changes for scenarios 2, 3, and 4 with varying MTTR and MTBF throughout the life cycle. Each of these parameters is a primary input into the SODM.

Table 10. Systems Scenarios MTBF and MTTR (Years)

	2% Degradation Scenario 2			3% Degradation Scenario 3			20% Improvement Scenario 4		
	Both	Center	Term	Both	Center	Term	Both	Center	Term
Year	MTTR	MTBF	MTBF	MTTR	MTBF	MTBF	MTTR	MTBF	MTBF
2000	0.00029	3.99	0.68	0.00029	3.99	0.68	0.00029	3.99	0.68
2005	0.00032	3.61	0.62	0.00033	3.44	0.59	0.00024	4.79	0.82
2010	0.00035	3.27	0.56	0.00038	2.97	0.51	0.00024	4.79	0.82
2015	0.00038	2.97	0.51	0.00044	2.56	0.44	0.00024	4.79	0.82
2020	0.00042	2.69	0.46	0.00052	2.21	0.38	0.00024	4.79	0.82

To reduce the number of SODM runs, simulations were run for every fifth year with results for in-between years being interpolated. For example, the Power Systems IA Benefits Team simulated the median annual delay for years 2000, 2005, 2010, 2015, and 2020 for each system scenario. Inclusive years were interpolated using a spreadsheet algorithm and the results plotted as hourly delay (median annual delay minutes/60) by scenario and year. Annual median hours of delay by improvement or degradation scenario are shown in Figure 7 below.

To determine the benefits, given a future demand and degradation or improvement scenario, it is necessary to develop cases for each alternative in terms of best case, worst case, and most likely case. The differences between the scenarios for each alternative were presented in median annual delay hours. For example, in the preferred alternative, the Power Systems IA Benefits Team developed three cases from SODM showing the differences in median annual delay hours between each case in five-year increments. Table 11 shows the three cases that were applied to each alternative; Figure 8 shows the differences in the annual delay hours for the preferred alternative.

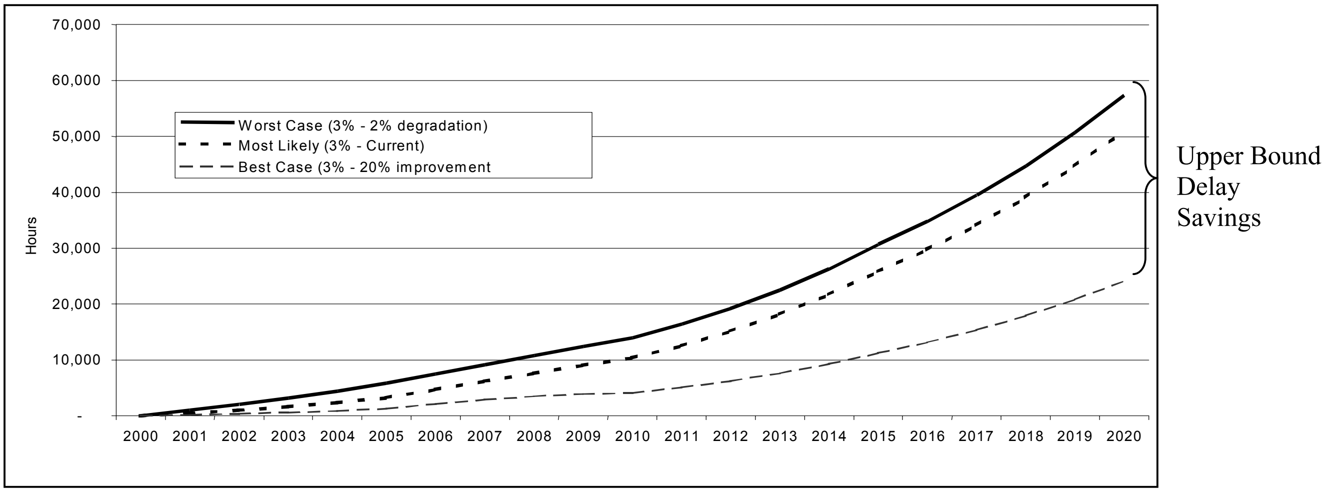


Figure 7. Systems Scenarios Measured in Median Annual Delay Hours

Table 11. Three Cases Examined for Each Alternative

Case	Degradation	Change
Best Case Benefits	3%	20% improvement
Most Likely Case Benefits	3%	None
Worst Case Benefits	3%	2% degradation

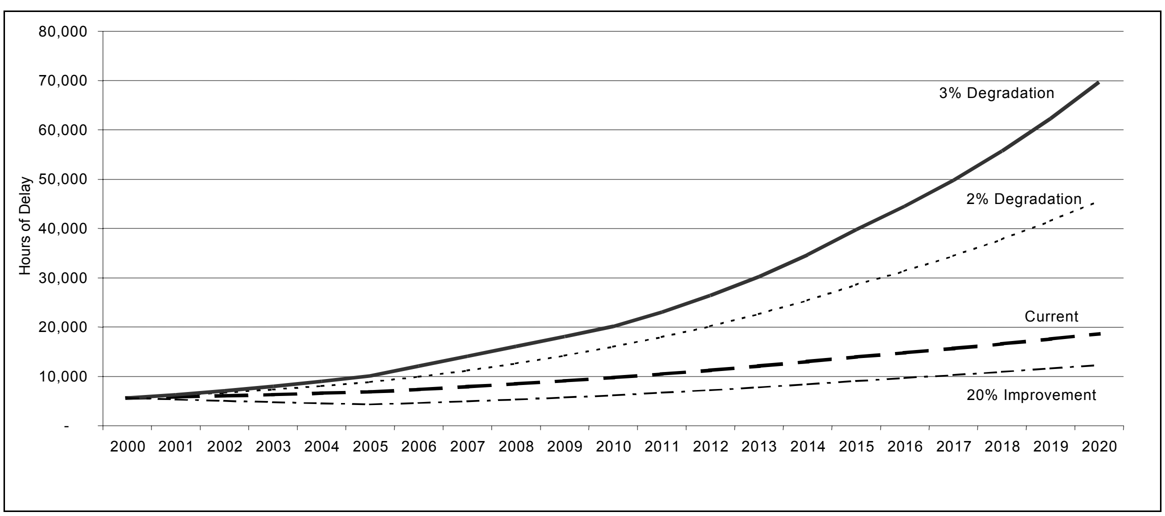


Figure 8. Benefits Cases for Preferred Alternative (Median Annual Delay Hours Difference)

3.5.2 FAA Benefit Impact

In addition to projecting the user benefits, identifying and projecting FAA benefits is the other critical part of the benefits analysis. Typically, with infrastructure programs (replacement of legacy systems, SLEP, or technology refresh), the bulk of the benefits will be in the life cycle cost savings to the FAA.

3.5.2.1 Mapping WBS Cost Elements to Acquisition Capabilities

Table 12, which can be used as a checklist, shows relationships between the key WBS elements that will affect the FAA benefits over the life cycle, i.e., the avoided cost portion. The FAA standard WBS Version 3.1 can be found at http://fast.faa.gov/wbs/wbssec.htm. This site is part of the Acquisition Management System (AMS).

Table 12. Key WBS Elements that Contribute to Cost Savings

FAA Benefits (Cost Avoidance) Intermediate Parameters To Quantify Metric	Corresponding WBS Element	WBS Description
Reduced costs due to more reliable and better designed equipment	5.2 Site Level Maintenance and Certification	All activities associated with site maintenance of hardware and software performed in an attempt to retain an item in a specified condition. It includes FAA direct, System Management Office, software maintenance, and contractor staffing.
Reduced equipment preventive maintenance	5.2.1 Periodic Maintenance – Hardware	All activities associated with scheduled FAA staff conducted non-recurring and recurring maintenance activities, and prime contractor maintenance activities. It includes all scheduled maintenance to accomplish periodic inspections, condition monitoring, critical item replacements, and calibration. Servicing requirements (e.g., lubrication, fueling, etc.) may be included under the general category of scheduled maintenance, as well as activities specific for certification.
Reduced equipment corrective maintenance times, e.g., reduced inspection/certification time	5.2.2 Corrective Maintenance Hardware	All activities associated with unscheduled FAA staff conducted non-recurring and recurring maintenance activities, and prime contractor maintenance activities. It includes all unscheduled maintenance actions performed (due to system/product failure) to restore the system to a specified condition. The corrective maintenance cycle includes failure identification, localization and isolation, disassembly, item removal and replacement or repair in-place, re-assembly, checkout, and condition verification. Also, unscheduled maintenance may occur due to a suspected failure, even if further investigation indicates that no actual failure occurred. This also includes activities related to packaging and shipping components to depot-level repair facilities.
Reduced sparing costs	5.8 Logistics	All activities associated with the depot level to support NAS prime mission equipment and associated support equipment.
Reduced sparing costs	5.8.2 Replenishment Spares	All activities associated with replacing exchange-and-replace core items and expendable items issued to FAA field sites in support of NAS equipment. It includes material products items stocked at the depot, and direct ship items ordered through the depot but stocked at other commercial or government sites.
Reduced sparing costs	5.8.3 Repair	All activities associated with FAA and commercial activities regarding depot-level repair of equipment in support of the solution. It does not include costs for site-level maintenance.

Table 12. Key WBS Elements that Contribute to Cost Savings, Cont'd

FAA Benefits (Cost Avoidance) Intermediate Parameters To Quantify Metric	Corresponding WBS Element	WBS Description
Reduced sparing costs	5.8.8 CDLS Contracts	All activities associated with commercial depot logistic service (CDLS) contract costs not captured elsewhere.
Reduced training time	5.9 In-Service Training	All activities associated with attrition and refresher training of airway facility system specialists and air traffic controller personnel who directly operate, maintain, or provide support functions of the solution. This includes contractor provided costs as associated with specific training. Training costs include course development, course conduct (including instructor and facilities costs), travel, and per diem costs for students.
Reduced re-engineering costs from less equipment that is obsolete beyond ESL	5.10 Second Level Engineering	All engineering activities associated with the delivery of service, including the development of modifications, documentation, configuration management, and testing. It also includes evaluation, prototype, test, and implementation of technology refresh initiatives, as well as FAA and contractor staffing and travel as applicable.
Reduced facility utility costs	5.11.2 Utilities, Buildings and Grounds Upkeep and Maintenance	All activities associated with efforts to routinely maintain, modernize, and relocate the buildings, structures, roads, grounds, and support equipment. It includes recurring costs of utilities (i.e., water, electric, gas, oil, etc.).
Reduced telecommunications costs	5.11.3 Telecommunications	All activities associated with maintaining, upgrading, or modifying operational and administrative communications services required to sustain the operation and maintenance of the NAS facilities. It also includes leases and other recurring telecommunication costs.

Note: It is very important that the variables driving the relevant cost categories can be tracked to the changes in the primary parameters, MTBO, MTTR, and the implementation schedule.

3.6 Estimate and Project the Total Dollar Value of the Change in Operational Parameters - Step 6

Since user benefits have been quantified into timesavings (Step 5, Figure 7), they must be monetized. Computing the total dollar value savings for user benefits involves estimating the direct operating costs savings of the expected capabilities of each alternative relative to the reference case.

In the Power Systems IA, the benefits team developed an "effectiveness factor" based on the expected quantity and functionality of the anticipated replacement of equipment for each funding alternative. The factor ranged from 40% for the "some ARTCC" alternative to 100% for the "all ARTCCs and TRACON" alternative. This scaling factor was applied to the estimated benefits.

It is up to the discretion of the respective IAT to make adjustments such as incorporation of an effectiveness factor to give an accurate portrayal of the alternative being evaluated.

The potential benefits that are based on hourly delay savings (see Figure 8) must be converted into dollars using Airline Direct Operating Costs (ADOC) and Passenger Value of Time (PVT). Refer to Appendix A, step 7 for more detail. Table 13 shows an example from the Power Systems IA and the differences in median annual delay hours for the three cases that were developed for one of the scenarios. These timesavings in hours were applied to the ADOC block hour costs and PVT to calculate the costs by alternative. The economic cost factors can be found in the Economic Information for Investment Analysis briefing package. [22]

Table 13. Avoided Life Cycle Delay Costs

Scenario	Best Case	Most Likely Case	Worst Case
Arrival Delay Hours	352,000	286,000	126,000
ADOC (BY$)	$741.6M	$602.5M	$264.7M
PVT (BY$)	$855.6M	$694.9M	$305.4M
Arrival Delay Total (BY$)	$1,597.2M	$1,297.3M	$570.1M
Extension to NAS Total (BY$)	$2,315.9M	$1,881.0M	$826.7M

Monetizing FAA Benefits (Avoided Costs)

This step applies when there are expected cost savings between the alternatives of the relevant WBS elements that are claiming FAA benefits. For programs that are claiming cost savings to the FAA, it involves taking the taking the total cost of the reference case and decrementing it by the non-avoided overlapping costs.[8] Typically, FAA benefits tend to accrue in the out years where it directly impacts the In-Service Management Implementation (WBS Level 5.0, the Ops Costs). Also, near-term benefits, which are not as common in infrastructure programs, in the Solution Development (Section 3.0) and Implementation (Section 4.0) can be realized. WBS elements may be claimed early in the life cycle, e.g., re-engineering critical LRUs to maintain a certain level of operational availability.

Table 14 illustrates a set of cost elements that overlap in the reference case and the alternatives. Once these costs elements are identified they must be decremented from the Reference case (part of the numerator or the B part of the B/C ratio) when computing the FAA benefits. For example, the reference case and the legacy systems will continue to require preventive site maintenance as the new acquisition is being implemented into the National Airspace System (NAS). Therefore, these non-avoided costs, which account for the parallel operations during the transitioning, (avoided costs) need to be decremented from the reference case.[9] It is necessary to provide risk-adjusted constant dollar streams to ASD-400 so that the Economic Analysis can be conducted.

[8] This is a recent change from some of the previous IAs where differences have been taken between alternatives.

[9] Preliminary ASR-9/Mode-S Benefits Basis of Estimate document is not completed at the time of this documents completion; however, this set of cost drivers is expected to have savings relative to the Reference case.

Table 14. Non-Avoided Costs that Overlap

Cost Drivers (FAA Benefit)	Reference Case $M	Alt. 1: ASR-9/Mode-S Site Approach $M	Alt. 2: ASR-9 SLEP/ Buy ATCBI-6 $M	Alt. 3: Acquire Replacement Radar $M
Logistics				
Site Level Maintenance and Certification				
Second Level Engineering				
Utilities				
Total				

3.7 Conduct the Economic Analysis - Step 7

The Economic Analysis considers the FAA life cycle costs, life cycle benefits, which include cost savings to the FAA and user benefits, the cost of the alternatives, the benefit-to-cost (B/C) ratio, NPV, and payback period to evaluate alternatives. Each of the benefits scenarios was applied to the alternatives analyzed by the IAT.

Using the ASD-400 Economic Analysis briefing package (January 30, 2003), which is posted in the ASD-400 shared drive; follow the annotated methodology. The steps in the methodology are:

1) Obtain specified inputs from both the cost and benefit teams. Inputs should consist of life cycle streams based on the high confidence risk-adjusted benefits and costs (20th percentile benefit and 80th percentile cost). Put each cost and benefit in increments of 5th percentiles.

2) Convert the constant dollar cost and benefit distributions to NPV dollars.

<u>Computation of NPV</u>

When step 1 is completed, the NPV must be computed. The formula below illustrates the computations that need to be applied for each year in the life cycle.

Using the OMB-specified real discount rate, apply the following formula on the stream of constant dollars.

$$\sum_{n=firstyear}^{n=lastyear} \frac{B_n}{(1+i)\hat{}(\mathrm{n}-\mathrm{n(firstYear)})}^{N}$$

where $\mathbf{B_n}$ is the benefit year **n**, **i** is the discount rate, **n** is the year in the life cycle, **n** is the last year in the life cycle.

Table 15 presents the discount factors that should be used when computing the NPV. Note: Two discount factors are illustrated: 1) generally, the real discount rate of 7% should be applied when at least a portion of the investment is user benefits, and 2) a real discount rate of 3.1% (10-

year maturity, 3.9% for a 30-year maturity) consistent with the real interest rates on treasury bonds and notes annotated in Office of Management Budget (OMB) Circular No. A-94. This rate is applied to the FAA benefits or avoided costs.

The real interest rate is adjusted to remove the effect of expected or actual inflation. Both the year-end and the mid-year factors are presented. The mid-year factor is adjusted by multiplying the year-end discount factor by the square root of the rate, e.g., for a 7% factor the multiplier is 1.0344. Discounting the costs and benefits must be completed for each alternative so the B/C ratios can be derived.

Table 15. Discount Factors – (3.1 and 7.0%)

Year	Time Period (N)	Year-end Factors (3.1%)	Mid-year Factors (3.1%)	Year-end Factor (7%)	Mid-year Factor (7%)
2001	0	1.00		1.00	1.00
2002	1	.970	.985	.935	.967
2003	2	.941	.955	.873	.9035
2004	3	.912	.926	.816	.844
2005	4	.885	.899	.763	.789
2006	5	.858	.871	.713	.737
2007	6	.833	.846	.666	.689
2008	7	.808	.820	.623	.644
2009	8	.783	.795	.582	.602
2010	9	.760	.772	.544	.563
2011	10	.737	.748	.508	.526
2012	11	.715	.726	.475	.491
2013	12	.693	.704	.444	.429
2014	13	.672	.682	.415	.401
2015	14	.652	.662	.388	.375
2016	15	.633	.643	.362	.350
2017	16	.614	.623	.339	.327
2018	17	.595	.604	.317	.306
2019	18	.577	.586	.296	.286
2020	19	.560	.569	.276	.2673

3) Run Crystal Ball on present value high confidence risk adjusted annual cost and benefit distributions (generated in the previous step) to determine the high confidence values for the economic measures.

Using Crystal Ball, risk-adjusted high confidence benefits for costs, NPV, B/C ratio, Return on Investment and payback period can be calculated for each alternative.

Figure 9 illustrates a frequency distribution of 1,000 runs using Monte Carlo simulation. Conversely, the high confidence for the user benefits is the risk-adjusted 20th percentile; the low confidence is the risk-adjusted 80th percentile.

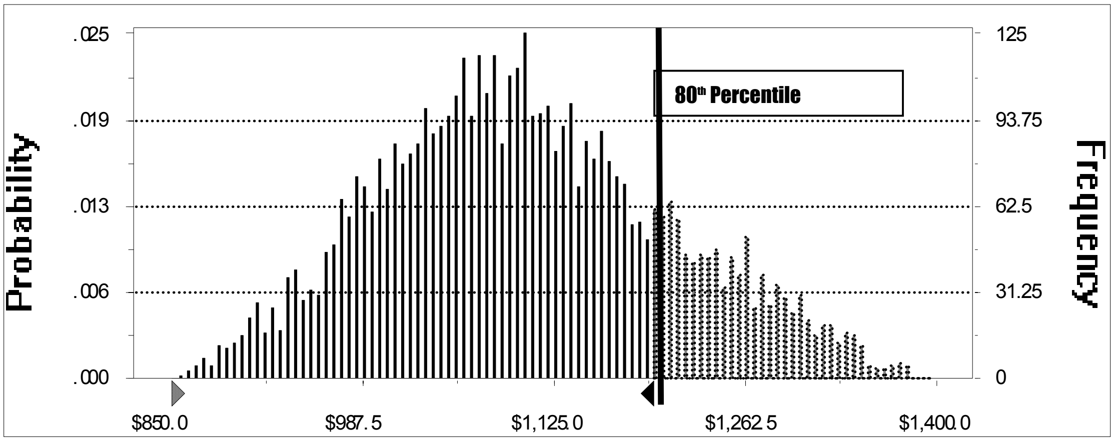


Figure 9. Hypothetical Frequency Distribution from Cost Monte Carlo Runs

Table 16 summarizes the economic analysis of the alternatives for the high confidence case. It represents the 80% confidence level for the NPV and B/C ratios; that is, based on the sensitivity analysis results, there is an 80% certainty that the B/C and NPV will be at least that amount. The summarized benefits and costs of the alternatives should be annotated in table and/or graphical formats as illustrated in Table 16 and Figure 10.

Table 16. Economic Analysis Summary of Power System Alternatives ($M)

Alternative	PV Benefits	PV Cost	Net Present Value	Benefit/Cost Ratio
Alternative 1 - some ARTCC	$209.6	$75.5	$138.0	2.9
Alternative 2 - all ARTCC	$264.1	$98.7	$167.3	2.7
Alternative 3 - ARTCC and large TRACON	$314.6	$121.7	$189.5	2.6
Alternative 4 - All TRACON and Surveillance	$422.9	$161.3	$265.0	2.7
Alternative 5 - VOR	$469.1	$194.9	$279.9	2.5
Alternative 6 – All Facilities	$529.0	$239.9	$296.4	2.3

Note: All values are risk-adjusted and were derived by Monte Carlo simulation.

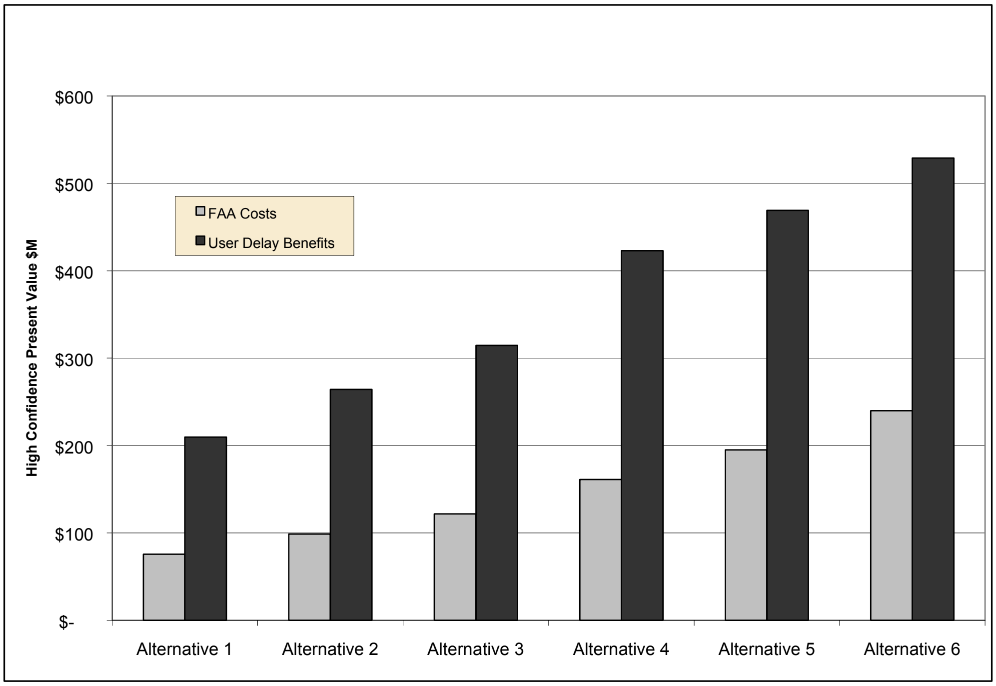


Figure 10. Benefits and Costs of Power Systems Funding Alternatives

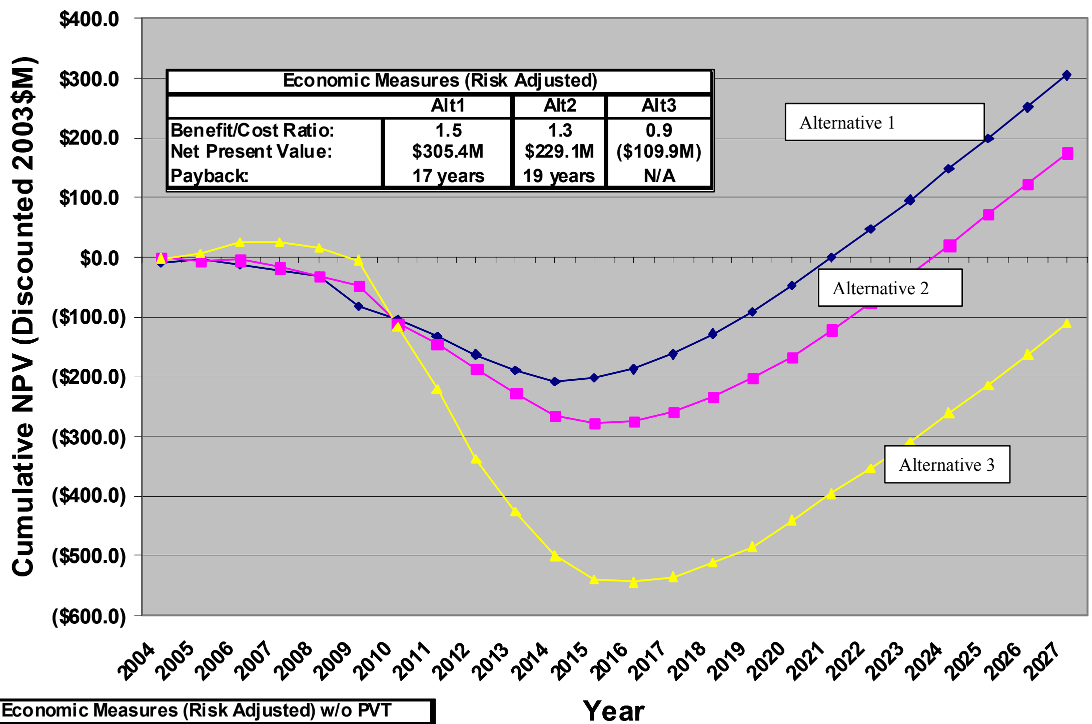
All monetized benefits must be expressed in the same year dollars, "constant dollars". If all dollar values are not expressed in the same year, then the effects of inflation on dollar values in different years will result in a particular benefit having one dollar value expressed in year X dollars and another value expressed in year Y dollars. This can lead to confusing and misleading benefit assessment results. Also, two benefits expressed in different years cannot be combined to yield a total benefit. If there are other benefit categories, then each category needs to be aggregated into the life cycle benefits stream.

Table 17 shows a generic illustration that presents the final results of the economic analysis for any IA. The results are illustrated with and without PVT; these two breakdowns are both required.

Table 17. Generic Presentation of Acquisition's Economic Analysis (NPV)

Quantified Benefits						Costs					
PV without PVT			PV with PVT			Cost (PV)			B/C Ratio (without PVT)		
High Conf	Most Likely	Low Conf	High Conf	Most Likely	Low Conf	High Conf	Most Likely	Low Conf	High Conf	Most Likely	Low Conf

Figure 11 portrays a standard graph that illustrates generic results of a payback period and NPV for three candidate alternatives.



Economic Measures (Risk Adjusted)			
	Alt1	Alt2	Alt3
Benefit/Cost Ratio:	1.5	1.3	0.9
Net Present Value:	$305.4M	$229.1M	($109.9M)
Payback:	17 years	19 years	N/A

Economic Measures (Risk Adjusted) w/o PVT			
	Alt1	Alt2	Alt3
Benefit/Cost Ratio:	1.2	1.1	0.7
Net Present Value:	$124.2M	$53.4M	($288.3M)
Payback:	20 years	22 years	N/A

Figure 11. Payback Period and NPV for Three Alternatives

Step-by-step procedures have been developed by ASD-400 through the Economic Analysis [21] to package the results in this manner. It is recommended that the analyst(s) familiarize themselves with the information as they are working on the IA or rebaseline effort.

Appendix A: Computation of Delay Savings

After the annual arrival delay savings are computed from the SODM runs, the final phase is to make the proper conversions and extrapolations into total timesavings and calculate cost savings in constant dollars so the Economic Analysis (Step 8) can be done. The timesavings always represent the differences between alternatives. See A-1 below where comparisons are made between the Requirement and the two Alternatives.

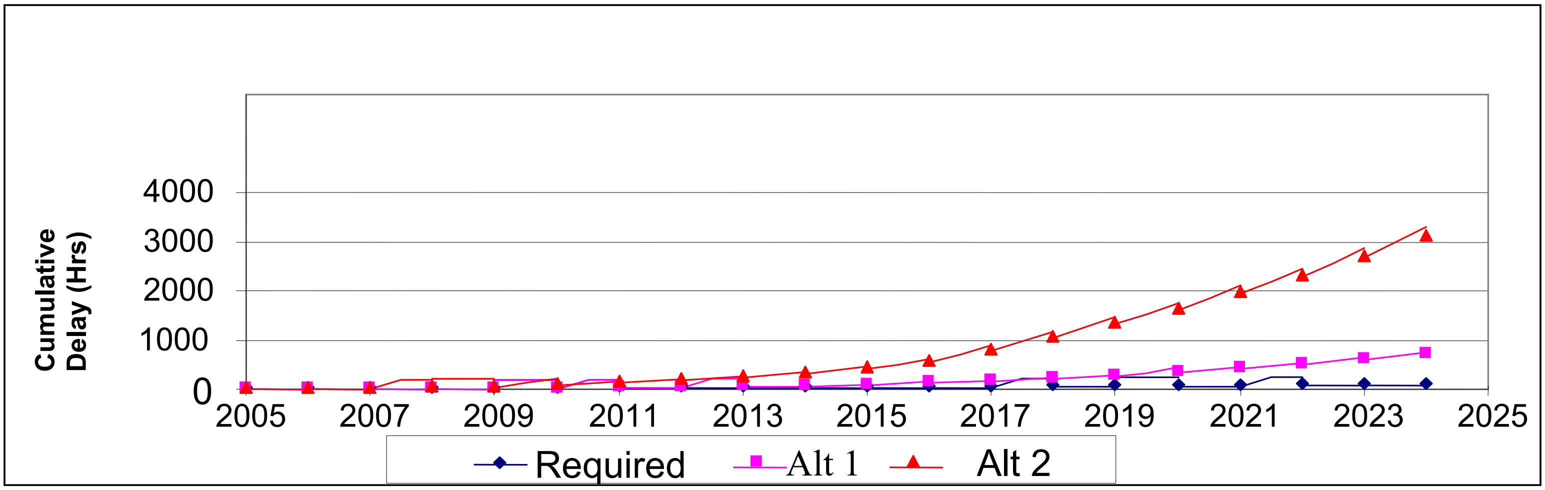


Figure A-1. Delay Estimates Between Alternatives

If all sites are estimated with the SODM runs, go to Step 2. If all sites are not estimated with SODM, then one additional step, Step 1, should have been applied to generate a proportional increase in the curves in Figure A-1. The remaining steps below pertain to any evaluation after the SODM results are generated.

1. **Calculate the *TAF Factor* by extrapolating results from 38 airports.** This step will account for additional air traffic operations to cover all the ASR-9 and Mode-S sites: The extrapolation is based on the number of operations reported through the TAF. This is a small adjustment factor since the major airports are setup in SODM. In the case of the ASR-9 sites, an adjustment of about 10-11 percent was made to reflect the additional operations at the non-SODM airports.

2. **Calculate a *SODM Factor* after running the model:** When running SODM, the minutes of delay from a baseline year(s), e.g., 2003 must be developed. This is the baseline number for minutes of delay. The *baseline delay* (column 2 in table A-1) is based on the product of the number of delays from outages and the average duration of the delay. For example, in the ASR-9 case, from 1998 through 2002 there was an annual average of 356 reported OPSNET delays (see Table 1) due to an ASR-9 outage. With an average delay duration of 45 minutes given a 15-minute delay is reported, the baseline delay value is 356*45 =***16020***. Since there is no noticeable upward trend in delays the identical number, 16020 is used for each year in the life cycle. The implementation of the alternatives beyond the baseline year may be several years later in the case of the ASR-9/Mode-S SLEP, i.e., 2010 and beyond. Therefore, it is important to calculate a future

delay value from the baseline inputs. The factor is derived by dividing the predicted minutes of arrival delay from the SODM runs by the baseline minutes of delay. For example, if the SODM results are 25,000 minutes, then a factor of 1.16 is applied to 2010.

3. **Develop a *Total Delay Factor*:** A total delay factor is calculated as a final multiplier to convert minutes or hours of delay from the SODM airport, plus the extrapolation in the previous steps into dollars. Multiplying the SODM factor (Step 2) by the TAF factor (Step 1), which may not be applicable of all sites are run in the model, gives the Total Delay Factor, e.g., 1.16*1.11=1.28. Table A-1 illustrates an example of how that value is generated for five representative years. For example, the increase in the SODM factor represents the benefits of the delivery of the enhanced capabilities at more sites.

Table A-1. Total Delay Factor

Minutes of Delay			Delay Factor		
Year	Baseline (2003)	SODM Predicted	(Step 2) SODM Factor	(Step 1) TAF Factor	*Total Delay Factor*
2010	16020	18583	1.16	1.11	1.28
2011	16020	23069	1.44	1.10	1.60
2012	16020	25312	1.58	1.10	1.75
2013	16020	25792	1.61	1.10	1.78
2014	16020	26753	1.67	1.10	1.84
2015	16020	27715	1.73	1.10	1.90

4. **Adjust for departure delays:** Once the predicted delays are generated from the "Total Delay Factor" in the previous step, delays that are not captured by SODM need to be calculated. Based on historical data, when there is a reported delay from OPSNET, given an outage (scheduled or unscheduled), or whenever a delay cause was reported, there were approximately five reported departure delays for every reported arrival delay (Table A-2). Since SODM calculates minutes of airborne delay in 15-minute bins, which in turn gets applied to arrival delay, a multiple of $((1-.167) \div .167)) = 5$ was used to account for the departure delays not reflected in the model, i.e., ground delays include ground stops and wait time in the taxi queue.

Table A-2. OPSNET Reported Delays

#	ID	Type	Region	Ops date	Equip Rep. Delay	Type of Delay	Equip Delays Accepted	Validated Delays
1	MEM	ASR	ACE	1/5/2002	12	Departure	12	12
2	TPA	ASR	ASO	1/2/2002	28	Departure	28	28
3	SLC	ASR	ANM	11/27/2001	17	Departure	17	17
4	CVG	ASR	ASO	1/21/2001	43	Departure	43	43

This factor of five is based on the ratio of reported OPSNET departure delays to reported OPSNET arrival delays during ASR-9 and Mode-S outages. A different factor could be used for another facility if the distribution of the types of delays (arrival, departure or enroute) is different. A sample record of a **NAS Equipment and Related Delays Events Details Page** that applies to each corresponding outage is illustrated below. This information can be found on the FAA intranet at http://aftechnet.faa.gov by clicking on the NAS Delays menu. The analyst can access each record associated with the respective airport by clicking on the airport located to the left side of the screen. A sample output from an outage at Tampa International Airport (TPA) for an ASR-9 outage appears as follows:

Delay Date: 1/2/02	*NAS Area: Terminal*
Arrival Equip Rep: 0	*General and Sub Cause: Hardware- Processor*
Departure Equip Rep:28	*NAPRS Code 80-Equipment*
En route Equip Rep: 0	*Delay Type: NAS Equipment*
Equip Delays Reported: 28	*MMS ID ZTL-2-4926*
Equip Delays Accepted: 28	……….
Reconciled Delays: 28	……………

Remarks: At 12:50 AM EST the Airport Surveillance Radar (ASR-9) failed. Investigation found channel A failed due to a Minimum Discernible Signal (MDS) alarm and channel B failed due to transmitter wave guide arcing alarm. Both channels were reset to restore service at 12:36 PM.

5. **Apply a downstream impact factor of 1.8 to the delays:** This accounts for a percentage of the late flights that may delay subsequent flights, i.e., a late first flight in the morning may impact the published scheduled arrival times of the next few flight legs from the same aircraft, and so forth. The total arrival and departure delay costs are multiplied by this factor. The factor is based on an MIT Lincoln Lab study that tracked itineraries of several flights using ASQP data to come up with the 1.8 factor.

6. **Calculate cancellations from OPSNET outage dates:** Every cancellation is assumed to cost the carriers an average of $6,000[10]. An average number of daily canceled flights in a representative month were derived from ASQP, and then subtracted from the number of cancellations that occurred on days where there was an OPSNET reported delay due to an outage. A scaling factor was applied to account for non-ASQP carriers not reflected in the data. Subsequently, an average number of cancellations derived per year were forecasted into the future until 2025. The following formula depicts the cost of cancellations by event due to an ASR-9 or Mode-S outage at an airport:

   (The number of cancellations at the respective airport on the outage day – average daily cancellations for the respective month the outage occurred)*(Total number of Ops – GA Ops)/ASQP Ops) * average airline cost from a cancellation - $6,000

   Table A-3 illustrates how the cancellations were applied for four reported OPSNET delay events. The cancellation-applied value is based on the difference in the average number of cancellations per day in the representative month, and the observed cancellations for the airport on the respective day. The adjusted cancellation value reflects other scheduled carriers that do not report through the ASQP. The cost was applied, giving the adjusted costs per event, e.g., on 4/22/2000 BOS had adjusted costs of $558K based on 93 cancellations due to the outage.

[10] Source: Office of Inspector General Audit Report, Air Carrier Flight Delays and Cancellations, July 25, 2000. In addition, the PVT is also reflected in the estimates. A conservative estimate of two hours per passenger lost from a cancellation is included when the time is converted to dollars.

Table A-3. Cancellation Adjustments

Locid	Date	Reported Cancels	Avg # of Cancels Per Day	Cancel Applied	Cancel Cost	Total Flight to ASQP Flight Factor	Adj. Cancels	Adj. Costs from Outage
BOS	4/22/00	80	19	61	367,600	1.52	93	558,000
BOS	4/26/00	61	19	42	253,600	1.52	64	384,000
ORD	2/1/99	97	19	39	231,429	1.49	58	348,000
CVG	1/21/01	25	58	7	105,484	3.57	26	156,000

Similarly, diversions can be factored into the analysis. Diversion information is available from the ASQP and can be derived like the cancellations. In the FFP2 IAR, Basis of Estimate, diversions were estimated at $6,200 per flight.

7. **Convert arrival delay savings (model output), departure delay savings (adjustment factor from arrival delay savings) and cancellations into dollar savings:** Arrival delay costs are calculated by multiplying the total delay time by the average ADOC and PVT costs for each year in the life cycle. Departure delays are computed by taking the product of the departure delay factor (5) * a ground cost factor of .58.

   Note: It is important to separate ADOC and PVT costs so that these subtotals can be used separately in the analysis to answer questions about total user benefits with and without PVT. (The ASD-400 Economic Information for Investment Analysis Data Package, dated April 2003, can be used to assist the analysts in calculating these costs. A copy of this document can be obtained from an ASD-400 IAT member.) Apply the ADOC and PVT cost as illustrated in Tables A-4 and A-5. The ADOC is $3,083/hour for air carriers, $616/hour for commuters, and so forth. The PVT of ~$28.60/hour (all purposes) with ~73 passengers per aircraft (assumes a 70% load factor as illustrated in Table A-6) also needs to be applied. The costs for ground delays (gate hold and taxi delays) are 58% of airborne operating rates.

Table A-4. ADOC by Aircraft Type

Aircraft Operating Costs	Variable Operating Cost Per Hour
Scheduled Commercial Service	2,635
Air Carrier w/o Commuter	3.083
Commuters Only	616
Air Taxi	457
General Aviation Only	202
General Aviation and Air Taxi	326
Military	1,709

Table A-5. PVT Factors

Category	Recommendation (per passenger, per hour)	Sensitivity Range Low	High
Air Carrier			
Personal	$23.30	$20.00	$30.00
Business	$40.10	$32.10	$48.10
All Purposes	$28.60	$23.80	$35.60
General Aviation			
Personal	$31.50		
Business	$45.00	No Recommendation	
All Purposes	$37.20		

Table A-6. Capacity and Utilization Factors

Category	Passenger Capacity	Passenger Load Factor	Avg. Occupied Seats	Cargo Load Factor
Scheduled Commercial Service	151.9	69.1%	105	44.6%
Air Carriers w/o commuters	158.9	69.1%	110	44.6%
Commuters	41.7	57.9%	24	33.1%
Air taxi	6.6	44.4%	3	NA
General Aviation	5.4	49.5%	3	NA
General Aviation and Air Taxi	5.5	49.0%	3	NA

Table A-4 above provides an illustration of how the passengers should be weighted when costing out the PVT. It is suggested that the analyst use the proportion of operations by category from the TAF to weight the number of passengers impacted at each airport.

Table A-8 illustrates the aircraft passenger distribution for six airports. For example, 46% (15.5%+30.8%) of the flights from BNA are either air taxis or GA aircraft. A sample calculation for ATL follows:

The average number of passenger's to/from the airport is based on the sum of the proportions of the respective categories.

> **A = Air carrier = 75% of total operations * number of average occupied seats for air carriers (110 seats)**
> +
> **B = Air taxi/commuter = 22.2% of total operations * number of average seats for commuters (24 seats)**
> +
> **C = GA = 2.5% of total operations * number of average seats for general aviation aircraft (three seats)**

Averaging the three aircraft categories (A+B+C) gives 88 occupied seats or passengers per flight to/from ATL.

Table A-7. Aircraft Category Distribution by Airport

Airport	Location	Itn_ac	Itn_at	Itn_ga	Itn_mil	Tot_itn	%AC	%AT	%GA	%MIL
ATL	Atlanta	780519	230708	25827	3524	1040578	75.0%	22.2%	2.5%	0.3%
BNA	Nashville	135579	40447	80384	4638	261048	51.9%	15.5%	30.8%	1.8%
BOS	Boston	279788	203488	37685	541	521502	53.6%	39.0%	7.2%	0.1%
CLE	Cleveland	151109	189762	28332	2692	371895	40.6%	51.0%	7.6%	0.7%
CLT	Charlotte	278460	146898	55881	3719	484958	57.4%	30.3%	11.5%	0.8%
CVG	Covington/Cinn, Oh	220772	337795	32913	1644	593124	37.2%	56.9%	5.5%	0.3%

Multiply the ADOC and PVT cost factors to reach a total delay cost for each alternative and compare the savings between each alternative in both constant and then-year dollars. Note: Inflation factors need to be applied.

8. **Summarize the benefits streams in constant dollars for input into the Economic Analysis:** Using Crystal Ball, a spreadsheet simulation software, generates frequency distributions in increments of five percent. Apply the risk-adjusted high confidence (20th percentile), most likely (50th percentile), and the low confidence (80th percentile) streams for each year in the life cycle. Using the ASD-400 briefing package, *Economic Analysis, January 30, 2003,* refer to pages 5 through 7 that describe the three methodology steps, and pages 8 and 9 for the presentation formats. Economic measures, B/C ratio, NPV, and payback period are calculated and will always be presented to the JRC for either an acquisition decision or a rebaseline. Supporting information such as the arrival delay and departure delay contribution can support the analysis through a sub-table as illustrated in Table A-8.

Table A-8. Avoided Disruption Costs by Benefits Scenario ($M)
(High Confidence Estimate - Alternative X Relative to Reference Case)

Measure	2005	2006	2007	2008	2009	2010-2025	Total
Total Avoided Costs							
ADOC							
PVT							
User Benefit Components:							
Arrival Delay Total							
Departure Delay Total							
Other Costs (Cancellations)							

Appendix B: Reference Documents

The following are data sources and reference documents that the analyst can refer to during when conducting the work:

1. Order 6040.15D, National Airspace Performance Reporting System, November 20, 1999.
2. Acquisition Management System (AMS)/FAA Acquisition System Toolset, www. http:\\fast.faa.gov.
3. *Cost, Benefit, and Risk Assessment Guidelines for RE&D Investment Portfolio Development,* October 1998, Source ASD-400.
4. *Economic Analysis of Investment and Regulatory Decisions – Revised Guide, APO98-4, January 1998.*
5. *A Simplified Approach to Baselining Delays and Delay Costs for the National Airspace System (NAS), Interim Report 12A, May 1999.*
6. *System Outage Disruption Model (SODM), A User's Guide*, FAA-ASD-400, June 2003.
7. *A Concept of Operations for the NAS in 2005,* ATS.
8. *Aviation System Capital Investment Plan*; June 1997; U.S. Department of Transportation, Federal Aviation Administration.
9. *Cost Estimation Policy and Procedures*, FAA Order 1810.3; May 1984; FAA Office of Aviation Policy and Plans.
10. *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs*, FAA-APO-98-8; June 1998; FAA Office of Aviation Policy and Plans.
11. *Federal Aviation Administration NAS System Requirements Document* NAS SR-1000.
12. *Federal Aviation Administration NAS System Specification Document* NAS SS-1000.
13. *Cost, Benefit, and Risk Assessment Guidelines for R,E&D Investment Portfolio Development*, Report No. WP-43-FA92F-99-1, Volpe National Transportation Systems Center, October 1998.
14. *National Airspace System Architecture Version 4.0,* January 1999; Federal Aviation Administration, Office of Systems Architecture and Program Evaluation (ASD).
15. *Standardized Cost and Benefit Information for JRC and MAR Presentations*; August 1996; Unpublished report by Federal Aviation Administration, Office of Systems Architecture and Program Evaluation (ASD).
16. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, Circular No. A-94*, October 1992.
17. *The Art of Benefits Prediction and the Statistical Science of Post-Implementation Assessment in Aviation Investment Analysis,* October 2000, revised June 2002.
18. *Reliability Predictions Report for the ASR-9/Mode-S Service Life Extension Program (SLEP), Northrop Grumman Corporation,* October 18, 2002.
19. *FAA Analysis Standards and Guidelines: FAA Standard Benefits Methodology,* November 2002.
20. *Air Carrier Flight Delays and Cancellations: Office of the Inspector General Audit Report, Report* #CR-2000-112, July 25, 2000.
21. *Economic Analysis Briefing Package,* ASD-400, January 30, 2003.
22. *Economic Information for Investment Analysis Data Package,* ASD-400, April 4, 2003.